Vernal Phosphate completes expansions and slurry pipeline without missing any concentrate shipments

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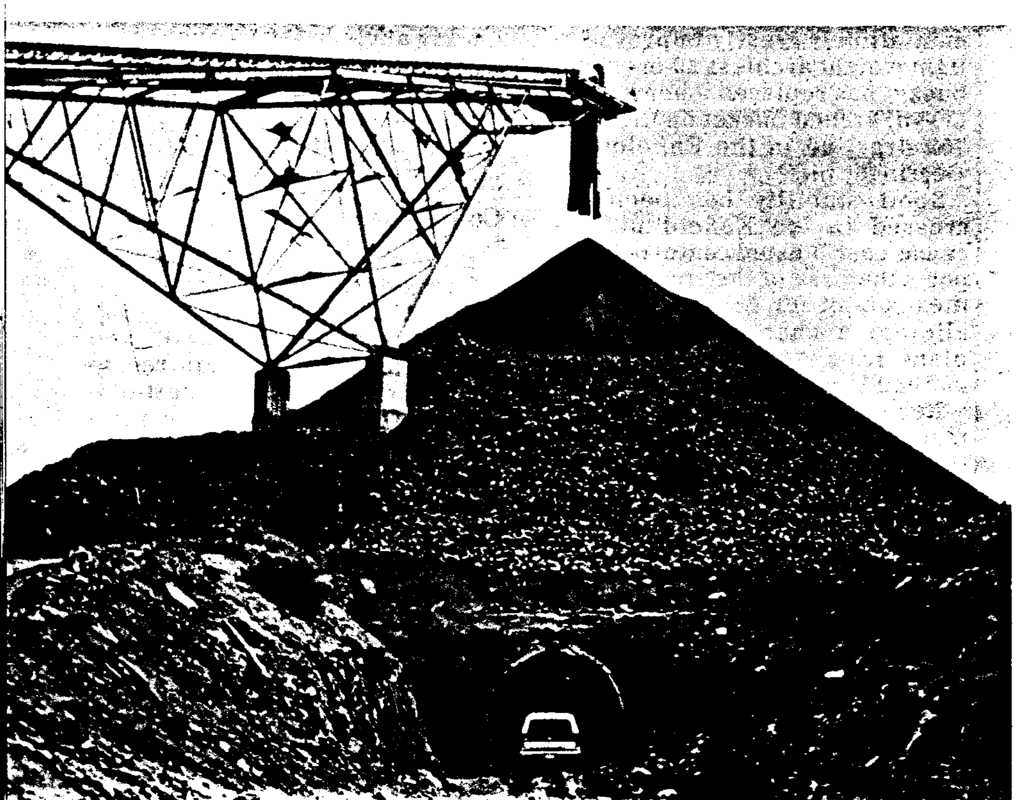

Introduction

The Vernal Phosphate Operation is located in northeastern Utah, about 18 km (11 miles) north of Vernal, about 280 km (175 miles) east of Salt Lake City, UT.

The plant began initial operations in 1961 under the name of the San Francisco Chemical Co. In 1981, Chevron purchased the operation from Stauffer Chemical Co. In 1982, plant capacity was doubled to about 72.6 kt/a (800,000 stpy) of phosphate concentrate.

From 1984 to May 1986, another expansion increased the capacity to 1.2 Mt/a (1.3 million stpy) of concentrate. It also incorporated a number of equipment and process changes designed to increase the overall plant phosphate recovery.

A 150-km (94-mile) slurry pipeline, the world's longest phosphate pipeline, was also constructed from the Vernal plant to a new Chevron Chemical and Fertilizer plant near Rock Springs, WY.

Over the past five years, plant expansions and the pipeline construction have been accomplished without missing a single concentrate shipment.

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Top: Aerial view of the Vernal operation showing the active mining area, concentrator, and tailings pond. Bottom: Crushed ore is stored in a 36.5-m (120-ft) high pile. Five feeders are located in the tunnel below the stockpile.

Mining operation

The Vernal deposit is a sedimentary deposit laid down on the bottom of an ocean floor during the Permian period. The sea covered vast amounts of the western US. Phosphate deposits associated with this environment occur in Montana, Idaho, Wyoming, and Utah.

In most areas, however, the phosphate is too deeply buried to be mineable. It is only where the deposit has been uplifted that mining may be feasible. The eastern end of the Uintah Mountains represents one such area. It is here that Chevron's 61-km² (15,000-acre) mining property is located.

After the Uintah Mountains were formed, most of the formations above the phosphate beds were eroded away. This left the ore covered by only 9 to 43 m (30 to 140 ft) of overburden. With an estimated ore reserve of 635 Mt (700 million st), the Vernal ore body represents one of the largest privately owned phosphate deposits in the world.

The phosphate ore body rests upon a 305-m (1000-ft) thick Weber sandstone formation. The ore is the bottom member of the Park City formation (Fig. 1). This formation also includes three other members that make up the majority of the overburden covering the ore.

The Lower Franson is a 9-m (30-ft) thick limestone bed that lies on top of the phosphate. Next comes the Mackentire, a 9-m (30-ft) thick red shale, siltstone, and sandstone mixture. Finally, the Upper Franson, which is an 11-m (35-ft) thick limestone bed.

The surface topography of the mine generally follows the dip slope of the erosion resistant portions of the Upper and Lower Franson members. The beds generally strike northeast-southwest and dip 5° to 23° to the south-southeast with an average dip of 8° to 10°. The mine elevation varies from 1.8 to 2.4 km (6000 to 8000 ft) above sea level.

The ore body is composed of 15 to 17 beds that range in thickness from 100 mm to 0.9 m (4 in. to 3 ft) (Fig. 2). Total bed thickness ranges from 5 to 6 m (17 to 20 ft) with an average ore grade of from 18.5% to 21% P_2O_5.

In the upper 2 m (7 ft) of the ore body, dolomite and chert are the main impurities. Calcite and chert are the major impurities in the lower section.

The major phosphate mineral in the ore body is collophane, an optically amorphous form of apatite. This collophane is present as small potato shaped oolites that range in size from 500 to 75 μm (35 to 200 mesh). These oolites are cemented together by a wide variety of materials including dolomite, calcite, chert, clay, collophane, and various mixtures of these minerals.

Overburden mining

Overburden mining consists of a cut-and-fill operation. Currently, only ores with an overburden depth of 12 m (40 ft) or less are being mined.

The overburden is first cleaned of existing vegetation by dozers. Topsoil averages 150 to 200 mm (6 to 8 in.) deep. It is stockpiled for use when the land is reclaimed. The overburden is drilled with a Driltech D40K using a 228-mm-diam (9-in.-diam) bit.

Holes are drilled on 7 m (22 ft) centers. A normal shot consists of 200 holes. This equates to about 76 dam³ (100,000 cu yd). Ammonium nitrate is used as the blasting agent. A nonelectrical detonation system is used to initiate the blast. The explosive factor is about 0.6 kg/m³ (1 lb per cu yd).

The blasted overburden is pushed down dip using Caterpillar D10 dozers to the area where the ore has already been removed. Most pushes are limited to less than 91 m (300 ft). Dozer capacity averages about 206 m³/h (270 cyph).

Ore mining

The top of the ore is clearly defined by an extremely hard dolomitic chert 255 to 255 mm (10 to 14 in.) thick. This is a low-grade material and, therefore, ripped off with D10 dozers and pushed in with the overburden.

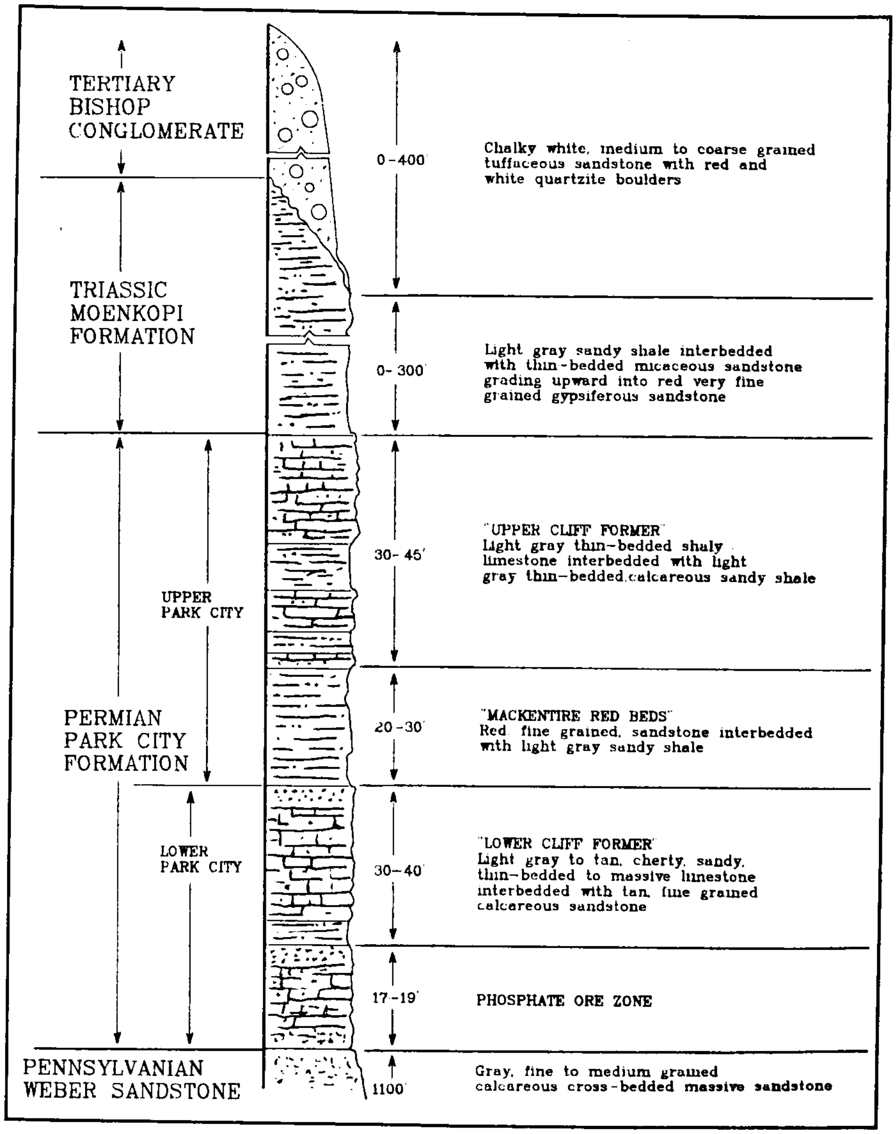


Fig. 1—Generalized stratigraphic column.

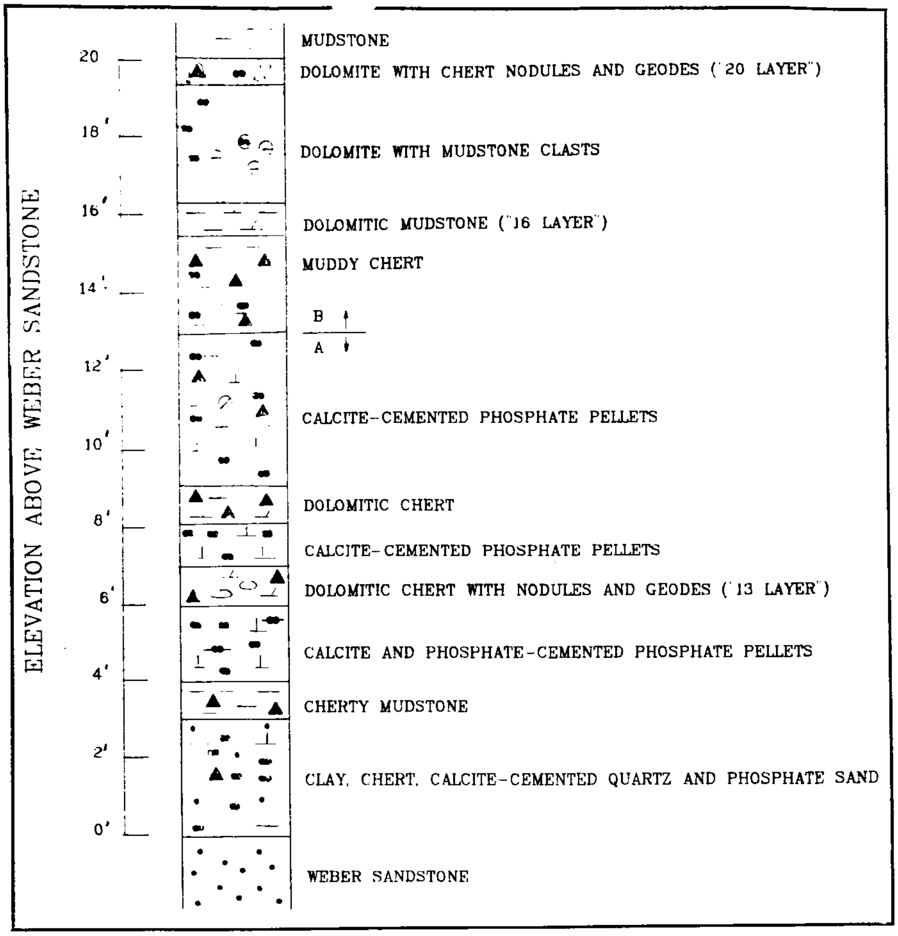


Fig. 2—Simplified lithology of ore section.

The ore is drilled with a Gardener-Denver PR80 drill using a 127-mm-diam (5-in.-diam) bit on 2.7 m (9 ft) centers. A normal shot consists of 23 to 46 dam^3 (30,000 to 60,000 cu yd). Ammonium nitrate is again used as the blasting agent. Typical usage is 0.4 kg/t (1 lb per st).

The ore is loaded in 50 t (55 st) 33-09 Terex trucks using a P&H 1200 hydraulic shovel. It is hauled to the in-pit crusher — a Stamler feeder breaker. In the feeder breaker, the ore is reduced to −254 mm (−10 in.) material. A 1-m (3.5-ft) cable supported conveyor belt carries it 915 m (3000 ft) to the coarse ore stockpile. Presently, mining is carried out on one shift per day at an average rate of about 1.2 kt/h (1350 stph).

Reclamation

Reclamation is an important part of the mining operation. The state of Utah requires that all lands disturbed in the mining operation be returned to the approximate same contour as before and replanted.

A bond is required for each disturbed acre. This money is not returned until a plot survey, taken a minimum of three years after the land has been replanted, shows that new vegetation is at least 70% of the original vegetation.

The minimal topsoil thickness and low annual precipitation rate (230 mm or 9 in. per year) makes this reclamation effort difficult.

After the overburden is pushed into a mined out area, it is shaped to the approximate original contour. Shallow depressions are often left to collect runoff, which enhances vegetation growth and provides water for wildlife.

Large boulders are often placed around the area to help recreate a natural appearance. Topsoil that has either been stockpiled or is being removed from the next mining area is placed on top of the overburden and spread by dozers and scrapers. Hay is often added to the topsoil as a mulch to conserve moisture and to minimize soil erosion.

Planting can only be done in the late fall or early spring when there is sufficient soil moisture to allow seed germination. Seeding is done with a range and drill pulled by a tractor or small dozer.

Up to 12 varieties of seed are used in the reclamation planting. Crested and intermediate wheatgrasses, so far, have shown the greatest success. Some trees and shrubs have also been planted after the grasses have become established but the success with these has been mixed.

Many techniques, such as hydromulching, hay mulching, and plastic screen mulching have been tried, to increase the survival rate of the germinating seeds. Each year, Chevron Resources' knowledge increases and the land reclamation becomes easier and more successful.

Milling

In this latest expansion, the Vernal staff was responsible for the process design and equipment selection. They received assistance from the Chevron Resources' San Francisco staff and the Chevron Research Center. The plant was engineered by Morrison-Knudson and built by Chevron Resources. Design work was begun in May 1984 and then came on-line and was operating in May 1986.

The ore from the mine contains 18% to 21% P_2O_5. It must be upgraded to 31.5% before it can be sold as concentrate. After upgrading, the concentrate must undergo additional grinding before it can be put into the slurry pipeline. At Vernal, processing takes place in eight separate steps (Fig. 3).

Primary grinding

The primary grinding circuit is a two-stage grinding process with each stage close-circuited, using screens. The purpose of this circuit is to liberate the phosphate oolites from the gangue material while minimizing the amount of phosphate that has to be discarded as slimes.

Five apron feeders are located under the ore stockpile. These are variable speed units and from one to five can be operated at a time. The feed rate is set by the operators and the speed of these units automatically adjusts to maintain a constant tonnage.

The ore drops off of the apron feeders onto a 1.4-m (4.5-ft) conveyor belt that feeds an 8-m-diam × 2-m (27-ft-diam × 7-ft) long Aerofall semiautogenous grinding mill (SAG). Enough water is added to control the density at 70% solids.

The ore remains in the mill until it can pass through the 19 mm

(0.75 in.) discharge gra[illegible]. The discharged slurry passes across a 19-mm (0.75-in.) trommel. The trommel oversize is conveyed to the ball mill while the trommel undersize drops into a sump and is pumped to three Model B Derrick screens for classification.

The screens have rubber decks with 4 mm (0.15 in.) slots that make about a 2-mm (10-mesh) split. The screen undersize flows by gravity to the ball mill discharge sump and the screen oversize flows by gravity back to the SAG mill. The SAG mill recirculating load averages between 40% to 60% at a new feed rate of between 335 and 380 t/h (370 and 420 st/h).

The SAG mill carries a normal ball charge of 6% and 7% using a mixture of 74 and 102 mm (3 and 4 in.) balls. Ball consumption is about 0.16 kg/t (0.4 lb per st).

The SAG mill has been lined with steel since it was first put into operation in 1982. In 1985, [illegible] rubber linings were tested. This looked encouraging and the entire mill was converted to rubber in July of this year.

Not enough tonnage has been put through the mill to develop definite usage rates. Preliminary data though, indicate that although the wear rate for rubber is higher than steel, the replacement costs of rubber should be competitive with steel. However, at least equally important to the Vernal operation is that it will require considerably less maintenance time to change out the rubber liners.

A 4 m-diam × 6-m (13.5-ft-diam × 20-ft) long Marcy ball mill is the second half of the primary grinding circuit. This mill is also rubber lined and uses 76 mm (3 in.) grinding balls.

The SAG mill screen underflow combines with the ball mill discharge and pumped to four Model B Derrick screens. Rubber decks with 1.5 mm (0.06 in.) slotted openings are used to make a 500-μm (35-mesh) split. The screen oversize gravity flows back to the ball mill while the screen underflow drops into a sump and pumped 2.4 km (8000 ft) to the concentrator.

Primary deslime circuit

The slurry from the SAG mill area is dumped into a 11.5-m-diam × 15-m (38-ft-diam × 50-ft) high agitated surge tank. This tank is normally operated half full of slurry. It was sized so that either the SAG mill or the concentrator could be down for an hour and the other could continue to operate.

The solids in the slurry from the primary grinding circuit vary from 500 μm (35 mesh) to submicron. Particles finer than 75 μm (200 mesh) must be discarded before flotation. This is because the flotation process has poor selectivity for particles below 75 μm (200 mesh). Although this size fraction represents about 30% of the incoming feed, the P_2O_5 content is low, 10% to 11%. Therefore, the P_2O_5 losses in this stream are not excessive. The separation of the −75 μm (−200 mesh) material from the coarser sands takes place in two stages.

In the first stage, the slurry is pumped through a bank of Krebs 660 mm (26 in.) cyclones operating at 103 kPa (15 psi). The overflow flows by gravity to the tailings pond. The underflow is pumped to the second stage, which consists of three 3 × 6 m (10 × 20 ft) Linatex hydrosizers.

In the hydrosizers, the velocity of a rising column of water is used to make the correct split. If necessary, the operator can adjust the water velocity to achieve the desired size split. The hydrosizer overflow is sent to the tailings pond. The underflow, at 75% solids, is diluted to 70% solids and flows by gravity to the primary conditioners.

Primary flotation

In the conditioning step, a mixture of fatty acid, diesel, petroleum sulfonate, and frother are added to the slurry as the flotation reagents. The fatty acid is the primary flotation reagent and the other chemicals either help extend the fatty acid or help stabilize the froth.

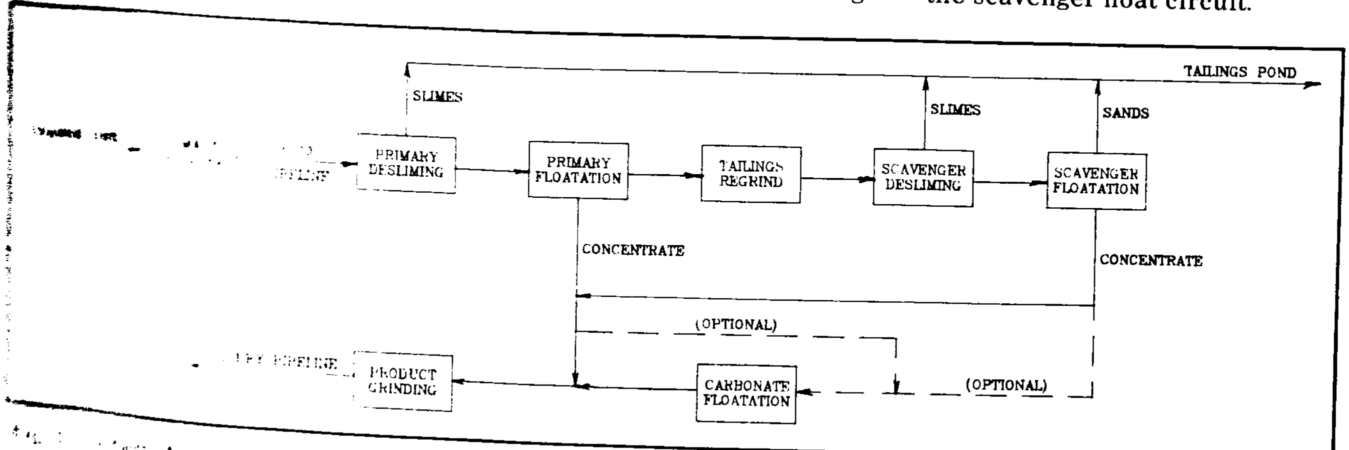
The slurry is mixed for four minutes in two agitated conditioning tanks. It then flows by gravity into two banks of rougher cells, each containing four Outokumpu 17 m³ (600 cu ft) float cells.

Water is added to dilute the feed to 25% solids. The air going to each cell is adjusted to achieve a calm froth surface with a minimum of pulp breakthrough. The rougher froth is cleaned in one, four-cell bank of identical cells. The tailings from the rougher and cleaner circuit are pumped to the tailings regrind circuit. The cleaner froth is pumped to the product grind circuit.

Tailings regrind

The tailings regrind circuit increases overall P_2O_5 recovery by liberating any phosphate oolites still cemented together in the rougher and cleaner tails.

The tailings are dewatered using Krebs 660 mm (26 in.) cyclones. The cyclone underflow at 70% solids flows by gravity to a 2.6-m-diam × 3.6-m long (8.5-ft-diam × 12-ft) Denver ball mill. The solids are fed once through this mill and then deslimed at 75 μm (200 mesh) in three stages of Krebs 510 mm (20 in.) cyclones. The underflow unit from the third desliming stage flows by gravity to the scavenger float circuit.



[illegible] sheet of Vernal milling operations.

Scavenger flotation

The solids are conditioned in agitated tanks using the same reagents and conditioning times as the primary float circuit. The feed to the float cells is diluted to 25% solids and floated in a four-cell bank of 142 m^3 (500 cu ft) Wemco cells.

The froth is cleaned in a four-cell bank of 8.5 m^3 (300 cu ft) Wemco cells. The cleaner tails are recycled back to the conditioning circuit. The rougher tails are pumped to the tailings pond, while the cleaner froth is pumped to the product grind circuit.

Carbonate flotation

Some ores from the mine are more difficult to concentrate efficiently than others. The carbonate flotation circuit increases recovery from these ores by depressing the phosphate and floating off the carbonate minerals.

This circuit is not yet operating. It is designed to operate as follows. The flotation concentrate is dewatered in cyclones to 70% solids. The reagents are removed from the surface of the phosphate oolites by scrubbing with sulfuric acid.

The slurry is conditioned with fatty acid at 70% solids for four minutes. It is then floated in two six-cell banks of 1.7 m^3 (60 cu ft) Galigher float cells at 25% solids.

The underflow is cleaned in a four-cell bank of 4 m^3 (150 cu ft) Wemco float cells. The froth from both banks is discarded to the tailings pond. The float cell underflow, which is now phosphate concentrate, is pumped to the product grind circuit.

Product grinding

The product grind circuit prepares the concentrate for the pipeline specifications — 30% to 35% −45 µm (−325) and 54% and 58% solids.

Primary and scavenger concentrates are dewatered in Krebs 660 mm (26 in.) cyclones. The overflow goes to tails, and the underflow, by gravity, goes to a 4-m-diam × 6-m long (13.5-ft-diam × 20-ft) Marcy ball mill filled with 32 mm-diam (1.25 in.-diam) balls.

Mill discharge is pumped to two 3 × 6 m (10 × 20 ft) Linatex hydrosizers. The water flow rate to the hydrosizer is adjusted to obtain the correct size split in the overflow. The underflow returns to the ball mill.

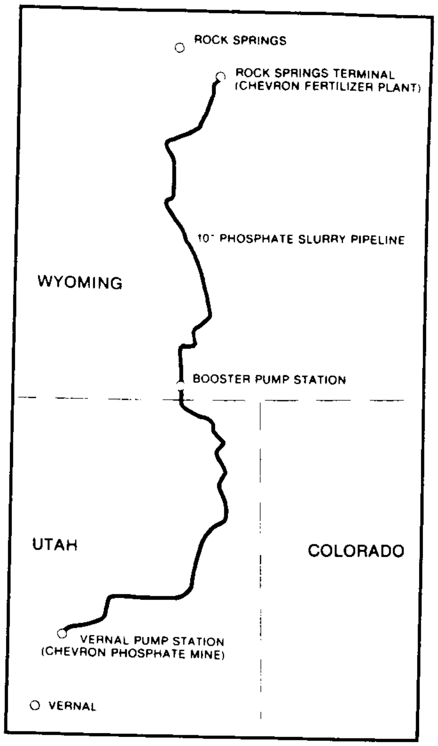


Fig. 4—Slurry pipeline.

The hydrosizer overflow flows by gravity to a 14-m-diam (45-ft-diam) Enviroclear high-rate thickener. Flocculant is added to help the solids settle. The thickener underflow, at 55% to 60% solids, is pumped to the slurry pipeline storage tanks. The thickener overflow goes to the tailings pond.

Tailings disposal

The course tailings represent 20% to 25% weight of the incoming feed. The fine tailings represent 30% to 35% weight of the incoming feed. Both are disposed of in the tailings pond, located about 1.6 km (1 mile) from the concentrator.

The current plan is to extend the height of the dam another 24 m (80 ft) by bringing in surrounding fill. It is estimated that this will require an additional 4.5 Mm^3 (6 million cu yd) of fill and about seven years to complete.

The dam will provide sufficient capacity for the next 20 years of operation at present production rates. Gravel drains and slurry trenches will be used to collect the seepage through the dam. This water will be pumped back into the tailings pond.

Miscellaneous operations

Several other changes to the operations occurred during the latest expansion.

Control panel — Modicon 584L's Programmable Logic Controllers were used throughout the plant to control the processing steps. However, instead of being hooked into a hardwired panel, as before, Cathode Ray Tube (CRT) screens are used to display the process flowsheet and current values of process variables.

Process variable values are updated every five seconds. The operator, by switching to controller screens, can control any of the process variables in his area. The operator can also start or stop all equipment from the CRT, but there is an option of local start and stop.

Process variables that exceed set points show up as an alarm on both the screen and a separate printer and are acknowledged and silenced from the screen. However, they do not disappear from the screen until the condition is corrected. The operators have readily adapted to this new system and find it easy to use.

Pumps and piping — All key process pumps are spared and the main pump generally has a variable speed drive. Georgia Iron Works all-steel pumps are used for the coarse material present in the SAG and ball mill discharge streams. The variable speed drives on these pumps are Nelson Fluid Drives.

All other pumps handle slurry where the solids are 500 µm (35 mesh) or finer. Warman rubber-lined pumps were selected for this service.

Water reclaim — The plant uses about 1580 L/s (25,000 gpm) of water to process 363 t/h (400 stph) of ore. All water and slurry waste streams flow back into a 20-hm^2 (50-acre) tailings pond. The solids settle out and the clear water is pumped back to the mill, using eight, three-stage vertical pumps. The only water to leave this circuit is what evaporates or goes with the slurry in the pipeline to Rock Springs.

Slurry pipeline

Before slurry pipeline construction, all the concentrate from Vernal had to be dried and trucked 217 km (135 miles) to a rail loadout facility. Consequently, a key component to the expansion was the slurry pipeline. It will provide a much cheaper means of transporting Vernal concentrate to its customers. This, in turn, will help ensure the long-term viability of the Vernal operation.

General description

The pipeline runs from the Vernal plant to the Chevron Chemical fertilizer plant, located about 5 km (3 miles) south of Rock Springs, WY (Fig. 4). The pipeline is 150 km (93 miles) long.

The line is constructed of 273 mm-diam (10.75 in.-diam) high tensile steel pipe. Wall thickness varies from 6 to 12.5 mm (0.25 to 0.5 in.), depending on the pipeline pressure. The pipe is buried at least 1.5 m (5 ft) along its entire length.

There is one pump station at Vernal and a booster station at milepost 48.3, about 3.2 km (2 miles) north of the Wyoming state line. The elevation profile is hilly. Special operating techniques are required to keep the slurry from flowing down the steep hills too quickly.

Design capacity of the pipeline is 2.5 Mt/a (2.8 million stpy) of dry concentrate. However, in the next few years the annual throughput is projected to be only 1 Mt (1.1 million st). Therefore, the pipeline will be operated in a batch mode rather than continuous.

Vernal pump station

Major equipment at the Vernal pump station consists of:

- Three 15-m-diam × 15-m tall (50-ft-diam × 50 ft) slurry storage tanks each with a 149-kW (200-hp) Philadelphia Gear agitator. At 55% solids, each tank has a usable capacity equivalent to 1.8 kt (2000 st) of dry concentrate.
- A 6 × 8 Warman pump (with a spare) to charge slurry to the mainline slurry pump.
- A 6 × 8 Warman pump to transfer slurry from the No. 1 tank to either of the other two tanks.
- Three mainline slurry pumps. These are Wilson Snyder triplex, single acting, piston pumps. Each pump is driven by two 745 kW (1000 hp) dc motors with a variable speed drive. Normally, two pumps operate and one is spare.

Slurry from the thickener underflow is pumped to No. 1 tank and transferred to either of the other two tanks. When a tank is full, the slurry is pumped through a 91-m (300-ft) test loop and then back to the same tank. Samples of the slurry are taken and checked for percent solids and percent 45 μm (-325 mesh).

The pressure drop across the test loop is also monitored. If the pressure drop through the test loop is within prescribed limits and the percent solids is between 54% and 58% and the −45 μm (−325 mesh) material is greater than 28%, then the slurry is allowed to be pumped through the pipeline. If the slurry does not meet any one of these specifications, it is either blended with other slurry to meet spec or sent back to the product grind circuit for reprocessing.

The slurry is charged to the mainline pumps at a rate of 272 t/h (300 stph). The valves to the slurry tanks are closed when enough tons have been delivered and water is injected into the mainline pumps until the entire slurry batch has been delivered to Rock Springs. Average pipeline velocity is 1.6 m/s (318 fpm). It takes the slurry about 26 hours to travel from Vernal to Rock Springs.

> The line has been unintentionally shut down twice with slurry in it. No problems were experienced either time when it was restarted.

Batch sizes have ranged from 0.9 to 5.9 t (1000 to 6500 st). Each slurry batch is followed by a 7.6-ML (2-million gal) water flush. If no slurry is scheduled after the flush is complete, the pumps are shut down and the pipeline left full of water.

The discharge pressure leaving the Vernal station is about 9.6 MPa (1400 psi) when pumping water and about 15.8 MPa (2300 psi) when pumping slurry. Discharge pressure at each station is closely monitored. If a pipeline valve is inadvertently closed, the pressure rises above a certain level and the pumps are automatically shut down before the pipeline ruptures.

Monitoring the discharge pressure also indicates whether a build-up of solids is occurring on the inside wall of the pipe and if it will then be necessary to pig the line to clean it out.

Booster pump station

Equipment at the booster pump station is identical to the Vernal station, except there are no slurry tanks or charge pumps. There are two water storage ponds so that if the Vernal stations goes down, there is enough water at the booster to continue pushing a slurry batch to Rock Springs.

By the time the slurry has reached the booster station from Vernal, the pressure has dropped to about 2 to 3.4 MPa (300 to 500 psi). The pumps at the booster station increase, the pressure back to 13.8 MPa (2000 psi).

At Rock Springs, the pressure in the pipeline is dissipated by forcing the slurry through ceramic orifice chokes. This drops the pressure from 2 MPa to 413 kPa (300 to 60 psi) and allows the slurry to be fed into a thickener and on into the rest of the plant.

Operating experiences

The pipeline has only shipped about 100 kt (110,000 st) through September. Several things have been learned, though, about its operation.

The pipeline was designed so it could be restarted with slurry in it after being down for up to 24 hours. The line has been intentionally stopped twice with slurry in it for two hours and restarted without problems.

The line has also been stopped unintentionally twice with slurry in for about two hours due to power outages. Again, no problems were encountered in the restart. Additional shutdown test for longer times are planned.

Start-up summary

From mid-May through September 1986, the Vernal plant has produced 127 kt (140,000 st) of concentrate. This rate is only 45% of actual capacity. That is due to low demand from the Rock Springs plant, rather than from any plant problems.

The plant has performed as expected. Although there have been numerous small problems, no major design problems or bottlenecks have been discovered. The plant is operating at design rates and soon should 10% above design.

Even though this new plant had to be built around an operating plant, the project came in on time, under budget, and without missing any concentrate shipments. ■

This material presented at the American Mining Congress' International Mining Show in Las Vegas, NV, October 1986.